ROEU 2017-18

Research Opportunities for Engineering
Undergraduates (ROEU) Program

1-1-2018

CFD/FEA of a Steam Methane Reforming Tube

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CFD/FEA of a Steam Methane Reforming Tube

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Chemical Engineering and Materials Science

Opportunity and Significance

- Computational Fluid Dynamics (CFD) and Finite Element Analysis (FEA) modeling can develop high-fidelity simulations of fluid flow and material stresses
  - ➢ Can be utilized to analyze how specific control strategies impact flow profiles and equipment material fidelity
  - ➢ Leads to control designs which increase profits while avoiding unnecessarily fast equipment material failure

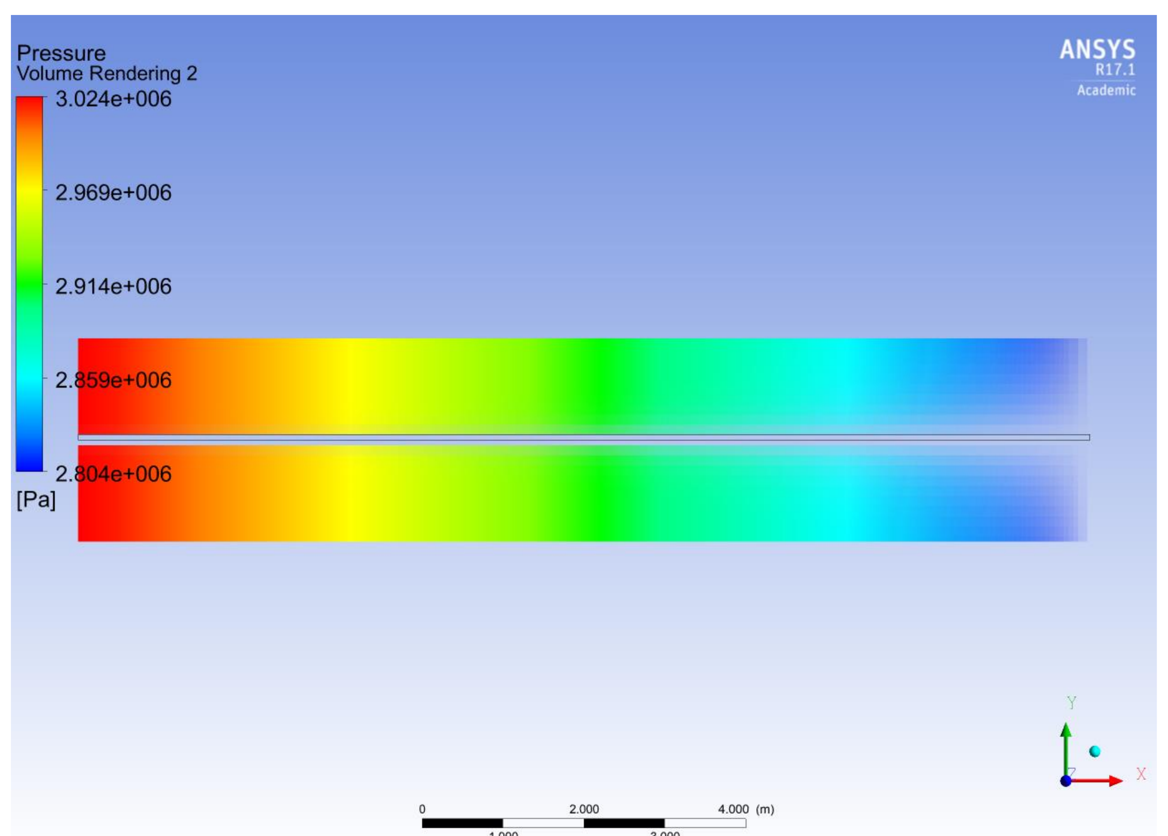

Fig. 1. Example of results which may be obtained utilizing CFD.

- Steam methane reforming is the primary method by which hydrogen is produced
  - ➢ An example steam methane reformer consists of 336 reforming tubes and 96 burners
- Increased efficiency in hydrogen production could enable hydrogen's usage as an alternative fuel

Related Work and State of Practice

- Next-generation controllers (e.g., economic model predictive control) may operate processes off steady-state
- It is critical to develop a framework for incorporating the relationships between control actions and equipment fidelity in control design

Technical Objectives

- Construct a robust CFD/FEA model of a steam methane reforming tube
- Perform steady-state CFD and associated FEA simulations for the tube wall to develop baseline data
- Perform closed-loop transient CFD with associated FEA simulations for the tube wall under PID control
- Compare thermal stresses/strains in the tube wall during the transient behavior and at steady-state
- Relate the thermal stresses/strains to properties of the control laws

Technical Approach

- Replicate reforming tube modeling and control efforts in [1] to develop baseline CFD simulations to couple with FEA analysis
- Develop simulations using ANSYS Workbench

Financial support from Wayne State University is gratefully acknowledged.

Technical Approach

- Proper meshing of the reforming tube is critical to being able to perform CFD simulations

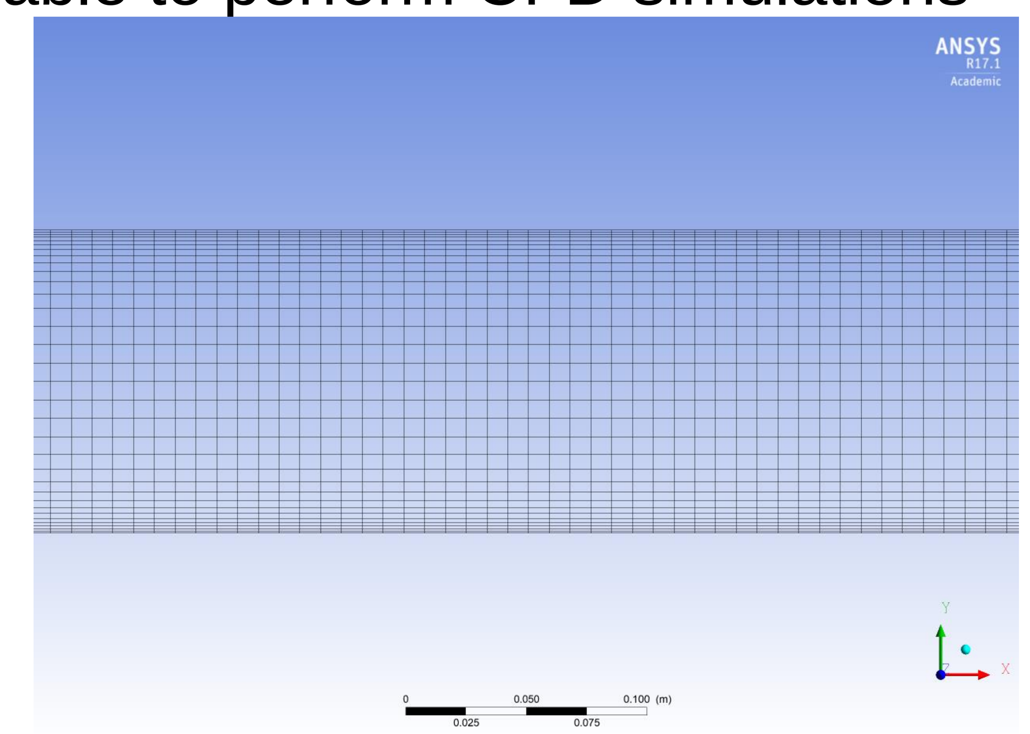

Fig. 2. Example of mesh for a reforming tube. Grid spacing is tighter near the walls.

- Relevant phenomena include:
  - ➢ Turbulent flow
  - ➢ Porous zone representation of catalyst packing
  - ➢ Gravity
  - ➢ Heat transfer
  - ➢ Species diffusion and reaction (CH_4, H_2O, CO, H_2, CO_2)

Next Steps for Development and Test

- Develop model for reforming tube wall for FEA analysis
- Perform FEA simulations for steady-state and transient cases

References

[1] Lao, L., A. Aguirre, A. Tran, Z. Wu, H. Durand, P. D. Christofides, 2016. "CFD modeling and control of a steam methane reforming reactor," *Chemical Engineering Science*, **148**, 78-92.

[2] Tran, A., A. Aguirre, H. Durand, M. Crose, P. D. Christofides, 2017. "CFD modeling of an industrial-scale steam methane reforming furnace," *Chemical Engineering Science*, **171**, 576-598.